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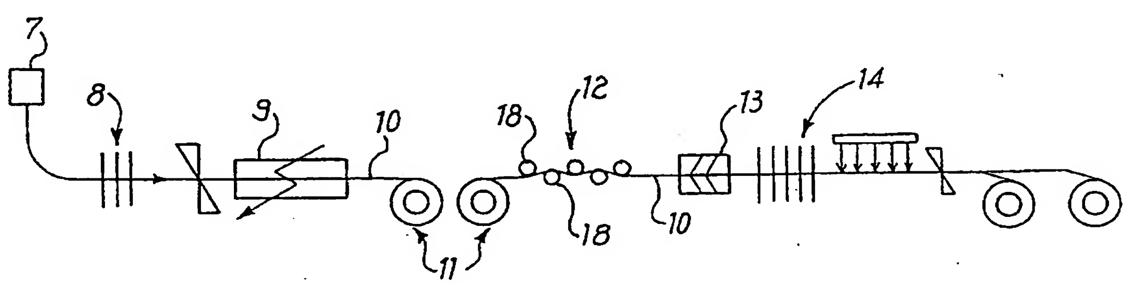
(54) Title: INTEGRATED CONTINUOUS CASTING AND IN-LINE HOT ROLLING PROCESS, AS WELL AS RELATIVE PROCESS WITH INTERMEDIATE COILING AND UNCOILING OF THE PRE-STRIP



(57) Abstract

An integrated continuous casting and in-line hot rolling process comprises in sequence, upstream of the hot finishing rolling, a step of coiling and subsequent uncoiling of a pre-strip having a thickness of 6–15 mm, followed by a step of plastic stretching to make easier the subsequent elimination of scale thus rendering possible in the hot rolling step the production of ultrathin coils with a thickness down to 0.6 mm which can replace, for particular applications, cold rolled strips. It is preferably provided, upstream of the coiling/uncoiling step, a step of induction heating with temperature being controlled. The plant carrying out such a process comprises for coiling/uncoiling (11) of the pre-strip (10) at least two coilers provided with a mandrel (20) preferably with an internally cooled shaft (21) being thermally insulated towards the outer central body (22) to which a pair of lateral steel segments (23) are advantageously assembled by interlocking fit.

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"INTEGRATED CONTINUOUS CASTING AND IN-LINE HOT ROLLING PROCESS, AS WELL AS RELATIVE PROCESS WITH INTERMEDIATE COILING AND UNCOILING OF THE PRE-STRIP"

The present invention concerns an integrated continuous casting and in-line hot rolling process, as well as the relative plant, for the manufacture of ultrathin steel strip in gauges down to 0.6 mm with such characteristics that, for particular uses such as deep drawing for car body parts, the rolled product obtained may replace a cold rolled product.

From patent application PCT/IT99/00050 in the name of the same applicant a process and plant are known for the manufacture of a pre-strip from 6 to 15 mm thick starting from a thin steel slab less than 60 mm thick. The process as per the present invention may be used for example downstream of this known process, expressly concerning a coiling and subsequent uncoiling system of the pre-strip 6-15 mm thick, such as to make possible in the subsequent hot rolling step the manufacture of ultrathin gauge coils but with characteristics similar to those of a cold rolled product.

In flat rolled steel manufacturing plants the use of temporary product coiling equipment before the hot finishing rolling mill is known, the purpose of which is to separate the low speed part connected with the continuous caster from the finishing mill which instead works at high speed, so as to form coils which can be used as a spare buffer. A typical application is the so-called "coil box" developed by Selco and used both for traditional plants and for so-called mini-mills which use thin slab technology.

As is known, the coil box in substance contains a series of entry rolls for bending and inviting the flat product to coiling, as well as motorized rolls for giving the necessary rotation to the product for the formation of the coil which in any case occurs freely, without a central core on which to be coiled and without a box shell. The equipment used, however, presents some drawbacks, the first of which is that of not being suitable for very thin gauges, for example of less than 15 mm, in which case there is an actual collapse of the coil. Moreover, the absence of boxing may lead to problems of non-uniform temperature, critical for obtaining the geometrical tolerances required for the hot production of ultrathin gauge (< 1 mm) coils, but with characteristics similar to coils obtained after a further cold rolling step, at least for particular uses.

It is true that patent US 4.703.640 tries to solve these problems by providing a box and the possibility of using a traditional mandrel, and that patent DE 4013582 supplies a possible solution with two coilers, each boxed in a casing, positioned one above the other, but both solutions have problems of technological and technical nature. Problems of the first type are due to the presence of heads and tails necessarily colder than the central part of the strip, which cause difficulties in the subsequent rolling, especially in the case of ultrathin gauges, giving rise in particular to:

- cobbles due to the so-called "refusals" of the rolling stand to accept material the head of which, over a few centimeters, shows temperature differences of several tens of degrees;
- out-of-tolerances of the first and last section of the strip (several metres), particularly important in the manufacture of ultrathin hot coils which can replace cold rolled ones in certain applications; and
- incorrect positioning or "tail climping" of the tail of the material with consequent damage of the same material and the working rolls.

Still with reference to patent DE 4013582, it can be noted that the strip tail being coiled which corresponds to the leading edge in the subsequent rolling, is subjected to a cooling that can reach about 100°C, in this way making the rolling of strips of any gauge, thin or ultrathin (> or < 1 mm) problematical. Moreover, from a technical point of view, the particular positioning of the coilers, placed one above the other, makes maintenance of the lower one difficult, above all in terms of time, some days being needed to disassemble the upper coiler in order to be able to have access to the lower one. In fact, before being able to intervene, it is necessary to wait for the temperature of the refractory to drop to an acceptable level, and before starting production again, the refractory must again be taken to temperature gradually so as not to cause thereto thermal shocks and damages.

Moreover, taking again into consideration the above-mentioned mini-mills for coil manufacture, one of their characteristics is having a particularly adherent layer of scale on the slab surface, as well as rolled-in scale caused by the upstream processes. To eliminate both types of scale, descalers working at pressures of up to 400 bars have been studied, which however have not solved the problem of completely removing the scale and the consequent defects caused by this on the strip surface, composed mainly of longitudinal lozenges due to scale rolled by the rolls into the strip, which in this way results unsuitable for example for the quality

standard for the outerly exposed parts of car bodies as per sectorial standards (for example DIN 1623).

One of the aims of the present invention is therefore to provide a process for the manufacture of ultrathin gauge hot rolled coils with cold rolled characteristics which do not present the above-mentioned problems of the prior art; this process includes the operating steps listed in claim 1, providing therefore a pre-strip coiling and uncoiling step between the roughing and finishing rolling, followed by plastic stretching of the material which facilitates the elimination of scale in a subsequent descaling step.

Additional operating steps, preferred or optional, are listed in the claims dependent on this.

The invention also includes a plant adapted to carry out the above-mentioned process.

These and other aims, advantages and characteristics of the process and relative plant according to the present invention will result more clearly from the following detailed description of a preferred embodiment of the plant, shown as a non-limiting example, with reference to the attached drawings in which:

Figure 1 is a schematic view of a part according to the present invention of a plant for the manufacture of ultrathin hot rolled coils with cold rolled characteristics, in a section between the roughing and possible heating step, downstream of the continuous caster, and the finishing rolling step;

Figure 1a is a schematic, perspective view of a complete plant including the part of Fig. 1;

Figure 1b is a schematic view of a possible construction example with two casting lines and one finishing line;

Figures 1c and 1d show sectional views of the coiling/uncoiling device as per the invention, respectively in the coiling and uncoiling step;

Figures 2 and 2a show a section of the pre-strip with adherent and rolled-in scale, respectively before and after plastic stretching of the pre-strip provided by the process of the present invention;

Figure 3 shows a schematic view, in cross section, of a possible mandrel embodiment to be used for the intermediate coiling/uncoiling coiler provided in the plant according to the present invention;

Figure 4 shows a front view of the mandrel of figure 3, with the central

body assembled by interlocking with the two side segments; and

Figure 5 shows a sectional view taken along the line V-V of figure 4.

The integrated continuous casting and in-line hot rolling process of the present invention for the manufacture of ultrathin coils includes in sequence, between the initial thickness reduction step, partially with liquid core, and the hot finishing rolling, a coiling and subsequent uncoiling step of the pre-strip with a gauge of 6-15 mm, so that it may have the desired characteristics of constant profile and temperature both transversally (between centre and edges) and longitudinally (between head and tail, passing through the centre).

A plastic stretching step follows immediately, which facilitates the elimination of scale in the subsequent descaling step, in this way making it possible in the subsequent hot rolling step to manufacture ultrathin coils in gauges down to 0.6 mm, which, for certain applications, may replace cold rolled ones.

With reference to the drawings, and in particular to fig. 1, the pre-strip 10, downstream of the continuous caster 7 with simultaneous thickness reduction (not represented) and possible subsequent roughing 8, is subjected to coiling/uncoiling in at least one coiler 11 provided by a mandrel 20 which will be better described hereinafter with reference to figures 3-5. Downstream of the coiler 11, or more than one coiler placed horizontally on the same line, a plastic stretching device 12 is provided, composed of a battery of not less than three rolls (upper and lower) 18, such as to perform a stretching of the material. This plastic stretching leads to the breaking of the continuity between the product and the layer of scale covering it, thus making the latter totally removable in the subsequent descaling step 13, for which reason it will not be necessary to adopt very high pressure descalers, as previously stated, combined with traditional-type mini-mills, before entering the finishing rolling mill 14.

It is to be noted that the coiling/uncoiling device may preferably include auxiliary equipment to favour the entry or exit of the pre-strip in correspondence with the openings of the box casing, parallel to the pass-line, so as not to leave the final part of the pre-strip outside the casing.

In particular, with reference to figures 1c and 1d, the coiling device 11 includes, inside an insulated casing 31, a non-expandable fixed mandrel 20 presenting on its periphery a pocket 21 for inserting the head. Wrapper rolls 33, 33' and 33" are also provided, represented in number of three in Figures 1c and 1d, being mounted on an oscillating arm and pushed inwards so as to be in contact

with the outer layer of strip coiled both in complete coiling conditions and therefore at the maximum coil diameter, and at the start of coiling, a condition in which these wrapper rolls are practically in contact with the central mandrel 20.

The casing 11 presents two axial peripheral openings 34 and 35, respectively for the entry of the pre-strip 10 to be coiled (Fig. 1c) and its exit when uncoiling (Fig. 1d). The two openings 34 and 35 are preferably defined and included between two respective pairs of rolls for favouring the passage of the pre-strip from outside inwards and vice versa.

Suitable means of control cause rotation of a deviating element 36, pivoting on the roller table 1, until it is directed towards the opening 34 so as to invite the pre-strip 10 to enter the device 11 and, pushed by the wrapper rolls 33, 33', 33", to enter, inserting itself into pocket 21, and be held by the mandrel 20 which, rotating anti-clockwise, as shown in Figure 1c, determines coiling on itself.

In correspondence with the opposite opening 35, an element 37, also having an end normally outside the opening, in a retracted position, can be caused to extend until it inserts this end into the opening so as to form the invitation to the tail of the pre-strip 10 to come out at the start of the uncoiling step, as shown in Fig. 1d, with the mandrel 20 rotating clockwise. The deviating or coiling invitation element 36, as also the extendable and retractable element 37 for uncoiling the pre-strip 10, may of course be made in any other equivalent way suitable for this purpose.

With reference to Fig. 1b, the device 11 is provided movable in a parallel direction to its coiling axis along guide tracks 38 represented in cross-section in Figs. 1c and 1d, on which it can be blocked in fixed coiling and uncoiling positions by means of blocking devices 39.

The moving of device 11 may occur both for maintenance reasons and above all for transferring the coil into an uncoiling position different from the coiling one so as to allow various casting and/or roughing lines to be connected with a single heating and finishing line downstream. On each line shown in Fig. 1b by the roller tables 1, 1', there are two subsequent coiling stations, one set back and one set forward, occupied alternately by the respective device 11 during coiling, as indicated by solid line in the drawing, while the representation of the same device 11 by a dashed line indicates the other possible position.

In correspondence with the central roll table 1c, aligned with the finishing mill 14 downstream, there are two possible coiling stations on which the device of

line 1 or line 1' is positioned respectively after coiling in the corresponding forward or backward position. Naturally, these positions are connected to each other by means of two pairs of tracks 38. While a strip is being uncoiled in the centre, there can be simultaneous coiling on two side lines in positions on different axes, so as to reach the central uncoiling position without interference.

With reference to figures 2 and 2a, there is a representation of what happens to the adherent scale 15 and the rolled-in scale 16 on a section of pre-strip 10, the latter caused in particular by upstream processes. Plastic stretching, shown in figures 2a by the arrows pointing outwards, causes lengthening, referred to a section of initial length L_o equal to:

$$E = \frac{L_l - L_o}{L_o}$$

Associated with the stretch, indicated by the arrows in figure 2a, which gives rise to this lengthening, is a plastic bending due to the passage through the rolls 18, which leads to the breaking of the adherent scale 15 and the rolled-in scale 16, much less ductile and more fragile than the steel, above all in the temperature range between 600 and 1300°C. Broken in this way, as shown in figure 2a with 15' and 16', the scale is completely removed in a subsequent descaling step 13 downstream of the device 12, so the pre-strip 10 presents itself at the entry to the finishing mill 14 with a surface free of any type of scale. It is therefore possible, after the finishing mill 14, to obtain a product free of surface defects.

It is to be noted that the above-mentioned plastic bending is achieved preferably by also providing a relative penetration movement between the upper and lower rolls 18, such as to produce bending in plastic conditions which ensures a stretching of the material of more than 2%. For this purpose a control system for the position of the rolls 18 and the force impressed by the device 12 can be provided. This control system preferably includes means able to keep stretching of the material within acceptable values (< 0.7%) of length variation, by using a mass flow variation measuring device, obtained by means of two encoders connected to the entry and exit of the device 12.

The process of the present invention can also preferably include, upstream of the coiler 11, a heating step obtained by means of an induction furnace 9, known already for example from patent EP 0415987. It is advantageous to introduce a regulation algorithm for the overheating of the pre-strip head and tail,

and in particular temperature control which involves the induction furnace, the coiler and the descaler downstream, with the aim of making it industrially and continuously possible to have a pre-strip suitable for rolling in the austenitic, dual step or ferritic fields in order to obtain hot production of coils in gauges of < 1 mm with the qualities of cold rolled ones.

Practical tests have in fact shown that controlled overheating of the head and tail of the strip are of great help in finishing mill rolling for preventing cobbles and obtaining the best product tolerances, especially in the manufacture of ultrathin products (< 1 mm). Moreover, particular strategies for managing the temperature of the coiler and induction furnace heating, combined with controlled cooling introduced by the descaler 13 downstream, represents the ideal solution for the pre-strip obtainable with the process of the present invention to be suitable for traditional austenitic rolling, two-step rolling between AR1 and AR3 or ferritic rolling under AR1 in the finishing mill. This flexibility allows the optimal crystallization form of the pre-strip to be chosen so as to reach the best quality depending on the type of steel to be obtained.

With reference to figures 3-5, a preferred embodiment is shown of a mandrel 20 to be used for the coiler 11. Figure 3 shows in particular the hollow central shaft 21 of the mandrel inside a central body 22 at the sides of which two steel segments 23 are provided, suitably lightened as is the central body 22. The shaft 21 is cooled by water flowing through the axial hole 24 and externally presents a layer of insulation 25 which, limiting the passage of heat between the shaft and the central body 22, reduces to a minimum cooling of the first section of the strip being coiled and corresponding to the uncoiling tail in subsequent rolling.

Figures 4 and 5, above all the first of these, show a preferred embodiment, of interlocking fit, to join the central body 22 to the side segments 23 by means of shaped fasteners 26, 26', which engage thicknesses 27 inserted to allow assembly, without the need for tie-rods or bolts as required in traditional constructions. These were particularly unreliable because of possible breaking of the tie-rods every 2-3 months, considering that the necessary replacement of the broken tie-rods each time led to a downtime of about two days so as to allow cooling of the refractory material and its subsequent heating.

The particular embodiment shown in figures 3-5 not only has the purpose of increasing the reliability of the mandrel and its ease of execution, but also of making countertension possible between the coiler 11 and the downstream

equipment, among which the first stand of the subsequent hot rolling mill. This also facilitates the so-called ferritic rolling in a hot rolling mill which, as stated before, can give the same results as those obtainable traditionally in the subsequent step in a cold rolling mill in order to produce coils of certain qualities, in particular in gauges of < 1 mm.

CLAIMS

1. Integrated continuous casting and in-line hot rolling process, characterized by the fact of including in sequence, between a step of liquid steel casting and subsequent thickness reduction until a pre-strip of 6-15 mm is obtained, and a finishing rolling step to obtain ultrathin coils down to a gauge of 0.6 mm, a coiling and subsequent uncoiling step of the said pre-strip, thus presenting characteristics of constancy of transversal and longitudinal temperature profile, followed by a plastic stretching step so as to facilitate the elimination of scale in the subsequent descaling, whereby the coils of ultrathin strip obtained in this way can replace, for particular applications, cold rolled coils.
2. A process as per claim 1, characterized by the fact of also presenting, between the casting step and the pre-strip coiling/uncoiling step, an induction heating step.
3. A process as per claim 1 or 2, characterized by the fact of including axial moving of the coiled pre-strip between distinct coiling and uncoiling positions.
4. A process as per claim 2, characterized by a regulation algorithm for the overheating of the pre-strip head and tail, and an algorithm which involves the induction heating, coiling/uncoiling and descaling steps, whereby the pre-strip can be rolled in the austenitic, dual step or ferritic fields.
5. A plant for carrying out the process of claim 1, characterized by the fact of including in sequence, along at least one line of passage (1), downstream of a continuous casting machine (7) and a possible subsequent roughing mill (8), upstream of a hot finishing mill (14), a coiling and subsequent uncoiling device (11) for a pre-strip (10) 6-15 mm thick, followed by a plastic stretching device (12) for the pre-strip and a descaler (13).
6. A plant as per claim 5, characterized by the fact of also including, between the said continuous casting machine (7) and the coiling/uncoiling device (11), an induction furnace (9), downstream of the possible roughing mill (8).
7. A plant as per claim 5 or 6, characterized by the fact of including at least two of the said coiling/uncoiling devices (11) placed horizontally on the same line of passage (1) as the pre-strip (10).

8. A plant as per one of claims 5-7, characterized by the fact that the said coiling/uncoiling device (11) includes auxiliary equipment (36, 37) to favour the entry and exit of the pre-strip (10) in correspondence with the respective openings (34, 35) of a box casing (31) in parallel with the said line of passage (1).

9. A plant as per any of claims 5-8, characterized by the fact that the said coiling/uncoiling device (11) includes in the said box casing (31) a non-expandable mandrel (20) able to bear a countertension with the equipment downstream.

10. A plant as per claim 9, characterized by the fact that the said mandrel (20) is composed of a central body (22) and a pair of lateral segments (23) which can be assembled by interlocking fit on the said central body (22) without bolts and/or tie-rods.

11. A plant as per claim 9 or 10, characterized by the fact that the said mandrel (20) includes inside this central body (22) a water-cooled shaft (21) with a layer of external insulation (25) towards the said central body (22).

12. A plant as per claim 5, characterized by the fact that the said plastic stretching device (12) is composed of a battery of upper and lower rolls (18) in a total number of at least three.

13. A plant as per claim 12, characterized by the fact that the said upper and lower rolls (18) are equipped with relative movement of penetration between each other, such as to produce bending in plastic conditions which ensures stretching of the material of more than 2%.

14. A plant as per claim 12 or 13, characterized by the fact of including a control program of the position of the rolls (18) and the force impressed by them into the pre-strip material (10).

15. A plant as per claim 14, characterized by the fact that the said device (12) includes means to control the stretching of the material within a maximum value of 0.7% of variation of the length by means of a mass flow variation measuring system.

16. A plant as per claim 15, characterized by the fact that the said mass flow measuring system includes two encoders connected to the entry and exit of the said device (12).

17. A plant as per claim 6, characterized by the fact of presenting a regulation algorithm for the overheating of the head and tail of the pre-strip (10)

through temperature control which involves the said induction furnace (9), the coiler (11) and a descaler (13) downstream of the device (12), whereby a pre-strip is obtained suitable for rolling both in the austenitic field and in the dual step or ferritic field.

18. A plant as per claim 7, characterized by the fact of including two casting/roughing lines (1, 1') and two or more coiling/uncoiling devices (11) for each line, positionable in respective coiling stations, parallel to the corresponding coiling stations on the other line, each device on a line occupying a coiling station in a staggered position, in the feed direction, with respect to the station occupied at the same time by the device (11) on the other line, the said devices being movable in axial direction until occupying the respective uncoiling positions, parallel to each other but not coinciding, on a central heating and finishing line (1c).

19. A plant as per any of claims 9-11, characterized by the fact that the said non-expandable mandrel (20) is contained in an insulated external casing (31) and is able to bear coil weights with a specific weight of even > 100 kg/m, being provided with at least three peripheral wrapper rolls (33, 33', 33") mounted at the end of a respective oscillating arm and two auxiliary devices (36, 37) in fixed positions of respectively coiling and uncoiling to favour the entry of the pre-strip (10) into the device (11) and its exit, respectively in correspondence with two openings (34, 35) practiced on the said casing (31) in parallel direction to the axis of the mandrel (20).

20. A plant as per any of claims 7 or 18, characterized by the fact that each device (11) is mounted, movable in parallel direction to the axis of the mandrel (20), on pairs of tracks (38).

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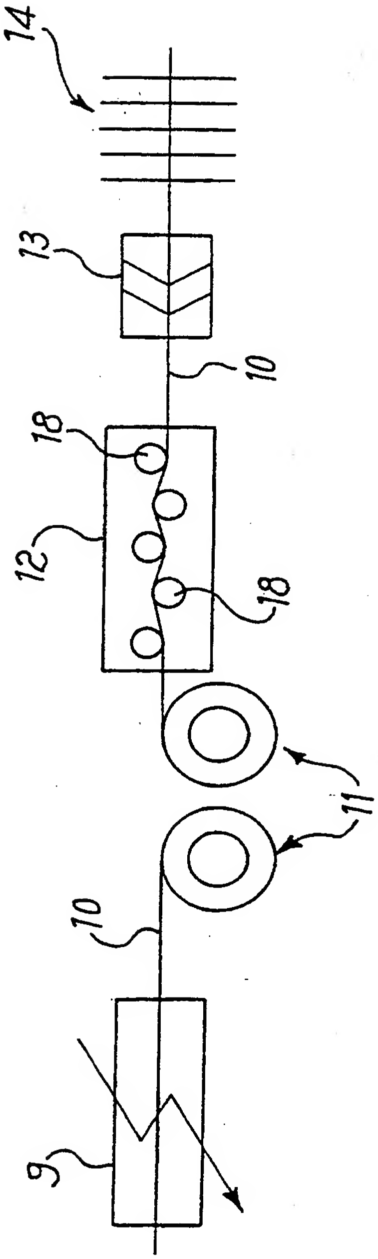


Fig.1

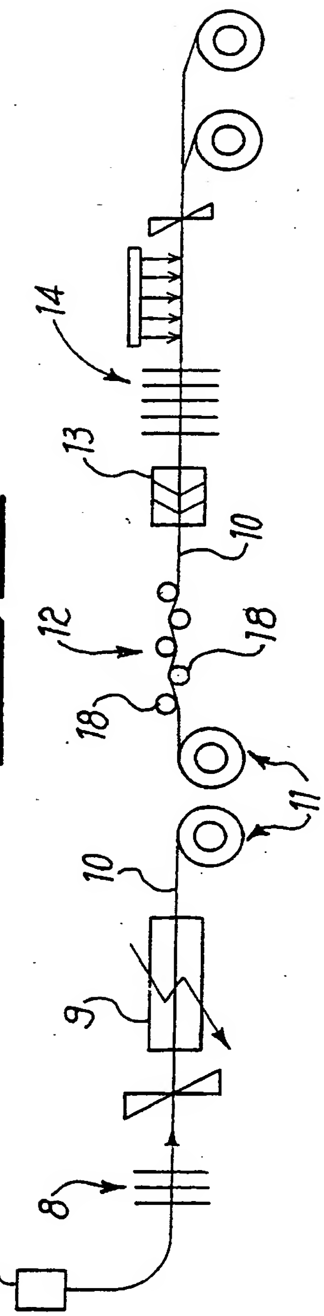


Fig.1a

Fig.1b

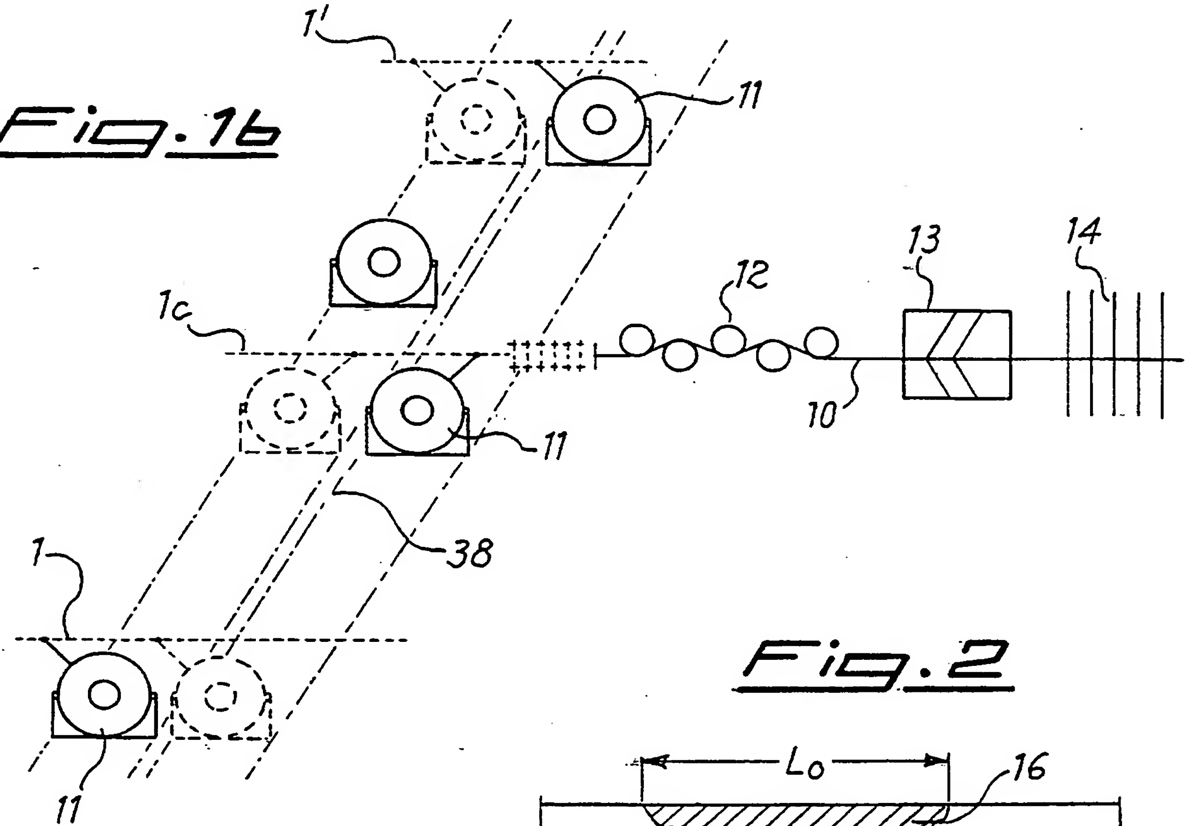


Fig.2

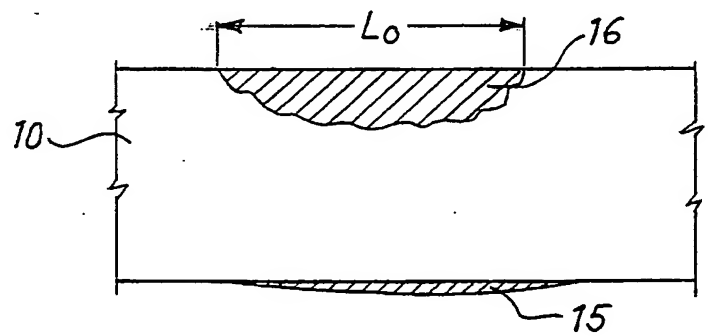


Fig.2a

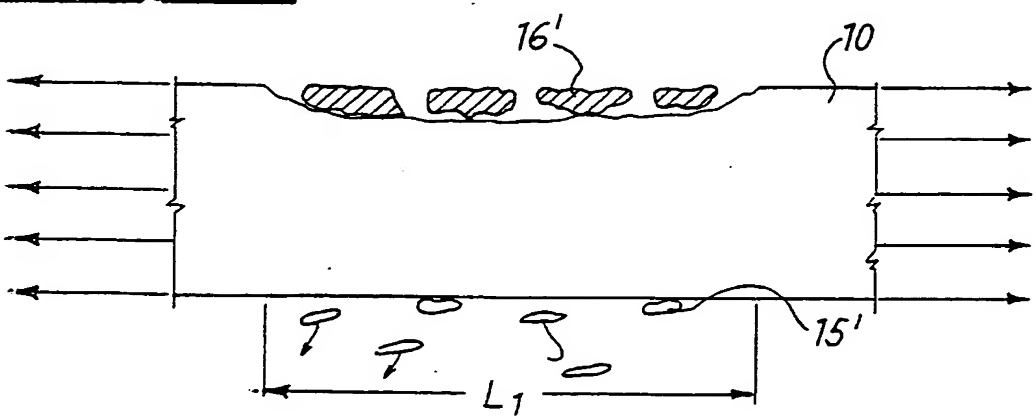


Fig. 1c

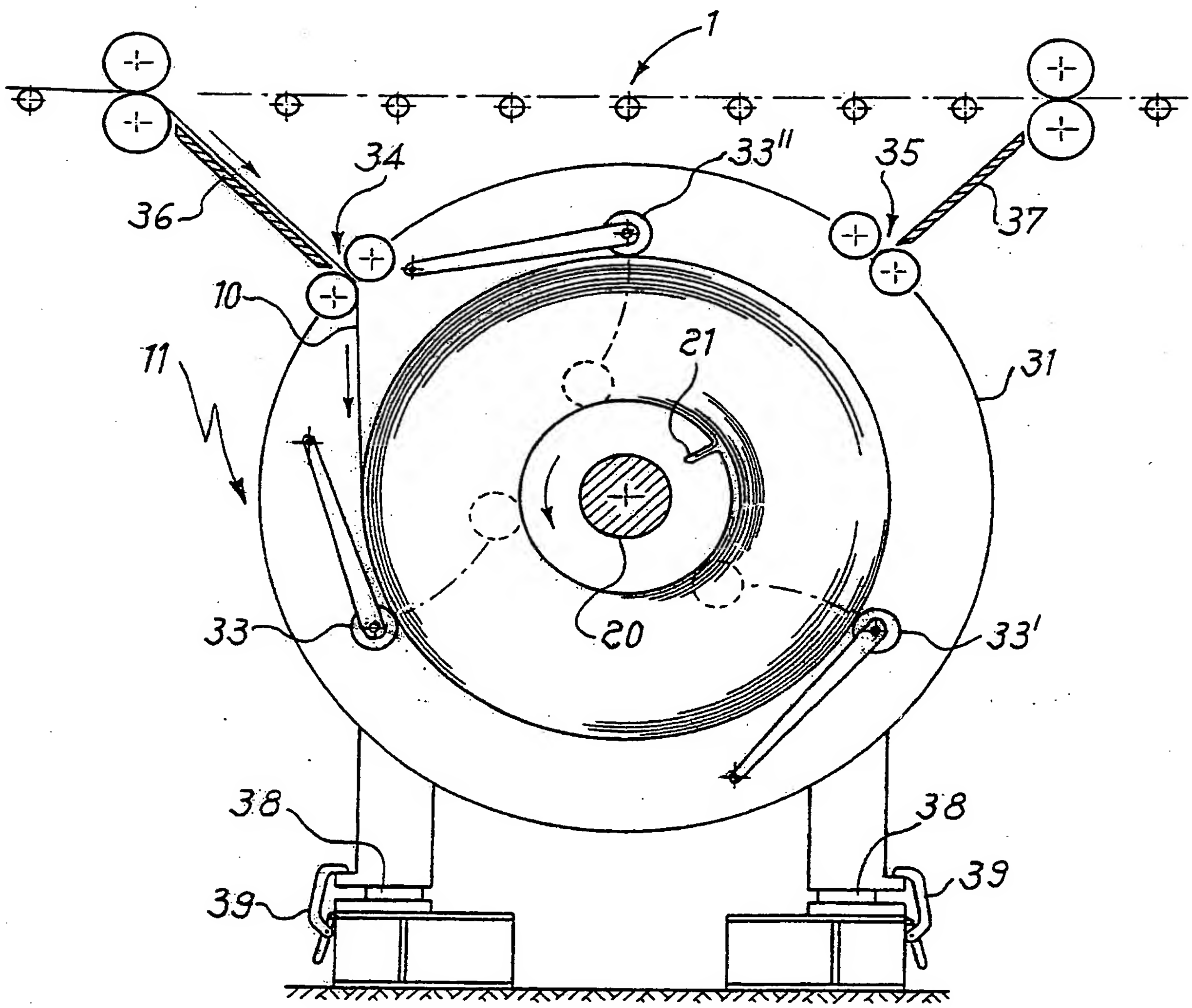


Fig.1d

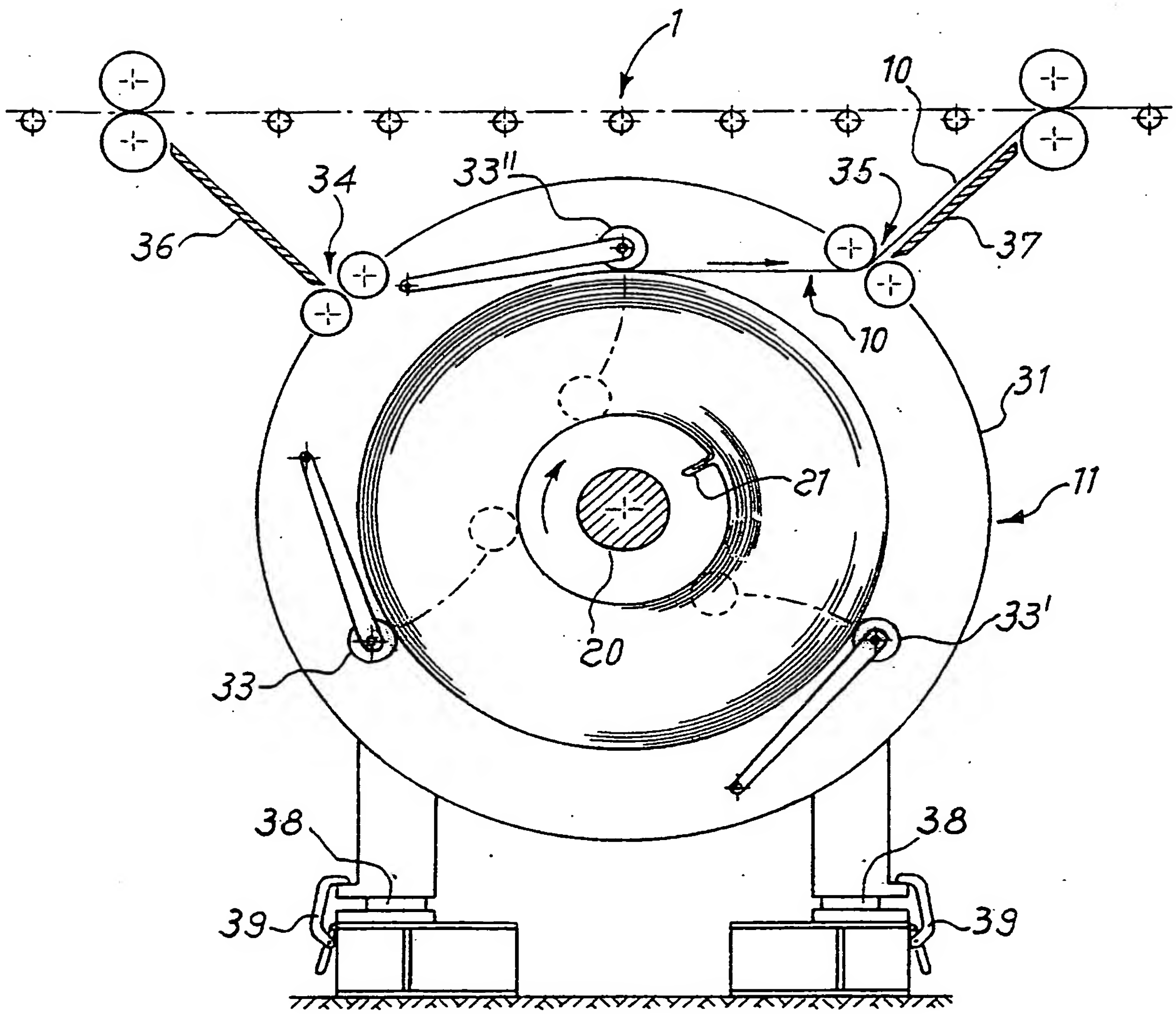


Fig. 3

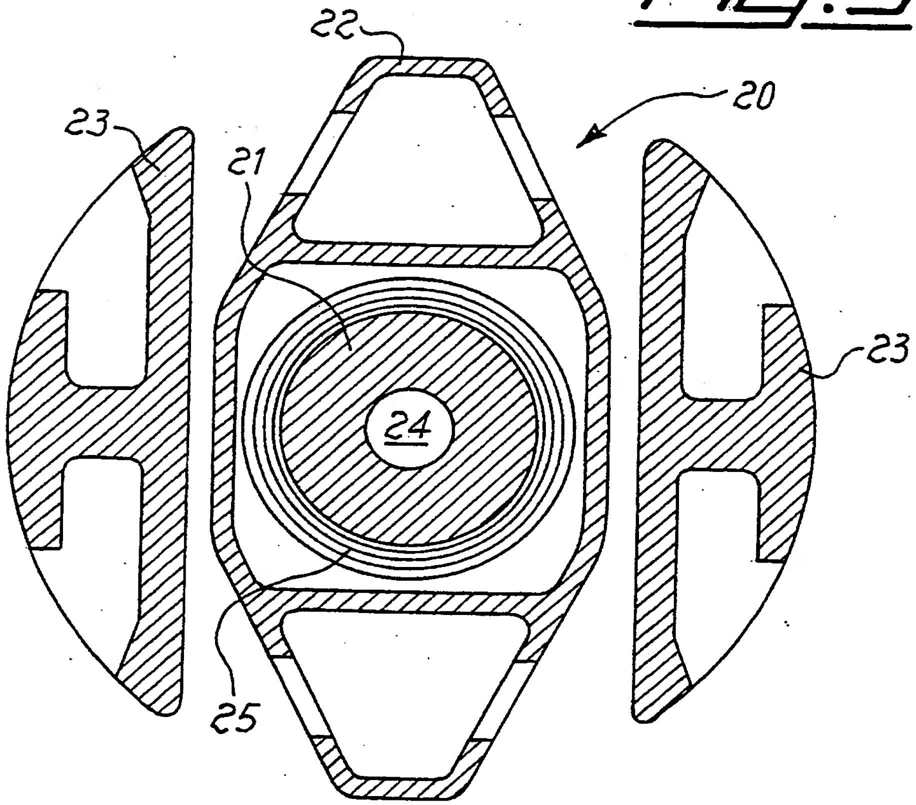


Fig. 4

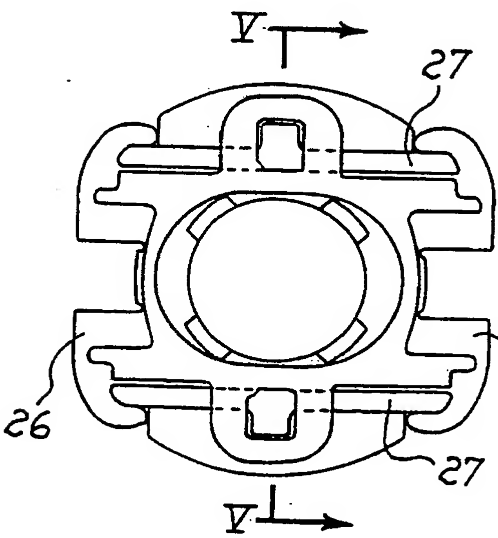
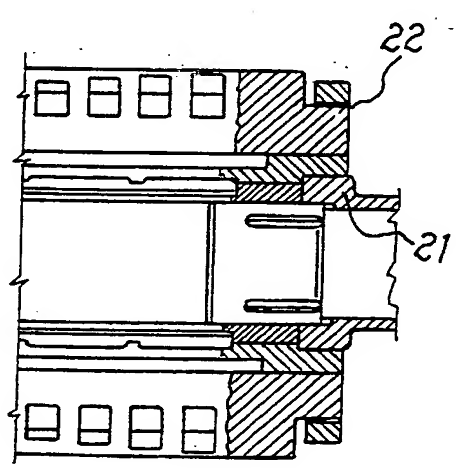


Fig. 5



INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
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B21C47/24

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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[X] Further documents are listed in the continuation of box C.

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Date of the actual completion of the international search	Date of mailing of the international search report
16 December 1999	22/12/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Plastiras, D

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